DRIVING APPARATUS, LIGHT-AMOUNT REGULATING APPARATUS,

AND LENS DRIVING APPARATUS

BACKGROUND OF THE INVENTION

5   Field of the Invention

The present invention relates to improvements of a driving apparatus and a light-amount regulating apparatus which are suitably usable in a shutter device and the like provided in an image pick-up

10   apparatus such as a digital camera.

Related Background Art

Digital cameras for opto-electrically converting a field image and recording it as information of a still picture image in a recording

15   medium by using a CCD and the like as a pick-up device have been more and more widely used. An example of the operation of exposure of those digital cameras will be discussed in the following.

The main power source is initially turned on

20   prior to photographing to put the pick-up device in its operating condition, and the shutter blade is hence held at its open position capable of exposing the pick-up device. Accordingly, storing, discharging and transferring of electric charges are

25   repeated by the pick-up device, and observation of the object field is made possible by the image monitor.

Upon pushing the release button, stop value and exposure time are determined corresponding to the output of the pick-up device at that time. Accordingly, when the diameter of the exposure

5   aperture needs to be narrowed, the stop blade is driven to be set at a predetermined stop value. Instruction of start of storing electric charges is then sent to the pick-up device from which stored electric charges are discharged. At the same time

10   the circuit for controlling the exposure time begins to operate upon reception of that start instruction as a trigger signal. After the lapse of a predetermined exposure time, the shutter blade is driven to its closed position for intercepting the

15   exposure of the pick-up device. Upon intercepting the exposure of the pick-up device, the stored electric charges begin to be transferred. The picture image information is thus recorded in the recording medium through an image writing apparatus.

20   Exposure of the pick-up device is blocked during the transfer of electric charges to prevent variation of electric charges due to undesired light during this transfer time.

Fig. 15 illustrates a small-sized stop

25   apparatus or shutter apparatus. In the apparatus, a motor for driving the stop blade or the shutter blade is formed in a ring shape, and its inner portion is

used as the optical path. Outer diameters of the
stop apparatus and shutter apparatus can be hence
reduced.

In Fig. 15, reference numeral 101 designates a
5   cylindrical rotor whose outer surface portions are
alternately magnetized into N and S magnetic poles.
Reference numerals 102a and 102b designate coils
which are respectively disposed along the axial
direction of the rotor sandwiching the rotor.
10   Reference numerals 103a and 103b designate stators
formed of magnetic material. The stator 103a is
magnetically excited by the coil 102a, and the stator
103b is magnetically excited by the coil 102b. Each
of the stators 103a and 103b is comprised of an outer
15   cylinder and an inner cylinder. The outer cylinder
has an outer magnetic pole portion which extends in
the axial direction in a planer form, and the outer
magnetic pole portion is disposed in a position
facing the outer surface of the rotor 101. The inner
20   cylinder also has an inner magnetic pole portion
which extends in the axial direction in a planer form,
and the inner magnetic pole portion is disposed in a
position facing the inner surface of the rotor 101.
Reference numerals 104a and 104b designate auxiliary
25   stators which are fixed to the inner cylinders of the
stators 103a and 103b, respectively. Reference
numeral 105 designates a coupling ring which is

formed of non-magnetic material, and serves to couple the stators 103a and 103b to each other with a predetermined phase shift. Upon supplying electric power to the coils 102a and 102b, the outer magnetic

5 pole portions of the stators 103a and 103b and the auxiliary stators 104a and 104b are excited, and the rotor 101 is rotated up to a predetermined position. Reference numeral 106 designates an output ring which is fixed to the inner surface of the rotor 101 and

10 rotates together with the rotor 101. Reference numeral 107 designates a plate on which grooves for engaging with pins on the output ring 106 are formed. Those grooves regulate the rotational range of the output ring 106. Reference numerals 108a and 108b

15 designate shutter blades which engage with the pins of the output ring 106, respectively, and whose opened condition is changed according to the rotational position of the rotor 101.

Fig. 16 illustrates another conventional

20 structure in which the outer diameter of a motor is greatly decreased without making its inner portion hollow.

In Fig. 16, reference numeral 201 designates a cylindrical rotor 201 whose portions 201a and 201b

25 are magnetized to the N and S magnetic poles, respectively. Reference numeral 201c designates an arm formed integrally with the rotor 201. A driving

pin 201d extends from the arm 201c in the rotational axial direction of the rotor 201. Reference numeral 202 designates a coil disposed along the axial direction of the rotor 201. Reference numeral 203

5   designates a stator which is formed of soft magnetic material, and excited by the coil 202. The stator 203 has an outer magnetic pole portion 203a which faces the outer surface of the rotor 201, and an inner cylinder which is inserted into the rotor 201.

10 Reference numeral 204 designates an auxiliary stator which is fixed to the inner cylinder of the stator 203, and faces the inner surface of the rotor 201. Upon supplying electric power to the coil 202, the outer magnetic pole portion 203a and the auxiliary

15 stator 204 are excited, and the rotor 201 is rotated up to a predetermined position. Reference numerals 207 and 208 designate shutter blades, and reference numeral 205 designates a plate. The shutter blades 207 and 208 are respectively rotatable about hole

20 portions 207a and 208a into which pins 205b and 205c of the plate 205 are inserted, respectively. The driving pin 201d slidably engages with elongate holes 207b and 208b. Reference numeral 206 designates a torsion spring which gives elastic force to the rotor

25 201 such that the driving pin 201d can be pushed against ends of the elongate 207b and 208b. When electric power is supplied to the coil 202 to rotate

the driving pin 201d together with the rotor 201
against the elastic force of the torsion spring 206,
the shutter blades 207 and 208 are rotated about the
hole portions 207a and 208a, respectively. The

5   aperture portion 205a of the plate 205 is thus opened
or closed.

When no current is supplied to the coil 202,
the elastic force of the torsion spring 206 brings
the shutter blades 207 and 208 into the condition

10   under which they close the aperture portion 205a.
When current is supplied to the coil 202, the rotor
202 is rotated against the elastic force of the
torsion spring 206. The aperture portion formed by
the shutter blades 207 and 208 is enlarged as the

15   magnitude of the current increases.

SUMMARY OF THE INVENTION

According to one aspect of the present
invention, there is provided a driving apparatus

20   which includes a rotatable ring-shaped rotor having
magnet portions divided along a circumferential
direction and differently magnetized; a first
magnetic pole portion formed extending in a direction
perpendicular to a rotational axis of the rotor, and

25   facing a face of the magnet portion perpendicular to
the rotational axis; and a second magnetic pole
portion sandwiching the magnet portion between the

second magnetic pole portion and the first magnetic pole portion, and facing another face of the magnet portion perpendicular to the rotational axis. In this driving apparatus, the condition of -

5 $0.333X+0.7>Y$ is satisfied where Y is a ratio of a central angle of each first magnetic pole portion relative to a central angle of each magnetized pole in the magnet portion, and X is a ratio of an outer circumferential length of each magnetized pole in the

10 magnet portion relative to a thickness of the magnet portion in a direction of the rotational axis. In this structure, the rotor can be held at each of its two rotational positions due to cogging torque without supplying current to the coil.

15 According to another aspect of the present invention, there is provided a light-amount regulating apparatus which includes the above driving apparatus, a plate with an aperture portion, and a light-amount regulating member. In this structure,

20 the amount of light passing through the aperture portion can be regulated by changing a direction of supplied current.

According to yet another aspect of the present invention, there is provided a lens driving apparatus

25 which includes the above driving apparatus, a lens, and a lens holding member. In this structure, the lens can be driven by changing the condition of

current supply, and the focal length of a light beam passing through the central portion of the rotor can be changed by changing a direction of supplied current.

5   Other objects and advantages besides those discussed above shall be apparent to those skilled in the art from the description of a preferred embodiment of the invention which follows. In the description, reference is made to accompanying

10   drawings, which form a part hereof, and which illustrate an example of the invention. Such example, however, is not exhaustive of the various embodiments of the invention, and therefore reference is made to the claims which follow the description for

15   determining the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

       Fig. 1 is a disassembled perspective view illustrating a first embodiment of a light-amount

20   regulating apparatus according to the present invention;

       Fig. 2 is a cross-sectional view illustrating the light-amount regulating apparatus of Fig. 1;

       Fig. 3 is a C-C cross-sectional view of Fig. 2

25   illustrating the condition under which blade members are closed;

       Fig. 4 is a C-C cross-sectional view of Fig. 2

illustrating the condition under which blade members are opened;

Fig. 5 is a graph showing the relationship between rotational position of the magnet and cogging torque;

Fig. 6 is a graph showing the relationship between size of the magnet, central angle of the magnetized portion in the magnet, and central angle of the magnetic pole portion in the stator;

Fig. 7 is a table describing structures of motor models of Fig. 7;

Fig. 8 is a graph showing experimental results of cogging torque, current-supply torque, and rotational phase;

Fig. 9 is a graph showing experimental results of cogging torque, current-supply torque, and rotational phase;

Fig. 10 is a graph showing experimental results of cogging torque, current-supply torque, and rotational phase;

Fig. 11 is a graph showing the relationship between size of the magnet of an experimental motor model, central angle of the magnetized portion in this magnet, and central angle of the magnetic pole portion in the stator of this motor model;

Fig. 12 is a disassembled perspective view illustrating a second embodiment of a light-amount

regulating apparatus according to the present
invention;

Fig. 13 is a disassembled perspective view
illustrating a third embodiment of a light-amount

5 regulating apparatus according to the present
invention;

Fig. 14 is a cross-sectional view illustrating
a fourth embodiment of a lens driving apparatus
according to the present invention;

10 Fig. 15 is a disassembled perspective view
illustrating a conventional shutter blade driving
apparatus; and

Fig. 16 is a disassembled perspective view
illustrating another conventional shutter blade

15 driving apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be
hereinafter described with reference to the drawings.

20 Figs. 1 to 4 illustrate a first embodiment of a
light-amount regulating apparatus according to the
present invention. Fig. 1 is a disassembled
perspective view of the light-amount regulating
apparatus, Fig. 2 is a cross-sectional view of Fig. 1,

25 Fig. 3 is a C-C cross-sectional view of Fig. 2
illustrating the condition under which blade members
are closed, and Fig. 4 is a C-C cross-sectional view

of Fig. 2 illustrating the condition under which
blade members are opened. In Figs. 3 and 4, bobbin
and coil are not shown, and a portion near a driving
pin 1h formed on a magnet 1 (described later) is
illustrated in an expanded fashion.

In those figures, reference numeral 1
represents the ring-shaped magnet in the form of a
hollow circular plate. The magnet 1 is formed of
plastic magnetic material, and acts as a rotor which
rotates about an axis of a central location of the
ring. Both opposite surfaces of the magnet 1
perpendicular to its rotational axis are alternately
magnetized into sixteen (16) N and S magnetic poles
along a circumferential direction, respectively. As
illustrated in Fig. 3, magnetized portions 1a and 1c
are magnetized into the N pole, while magnetized
portions 1b and 1d are magnetized into the S pole.
Their back side portions are magnetized into opposite
magnetic poles, respectively. Reference numeral 2
represents a ring-shaped coil. The coil 2 is
disposed adjacent to and on an outer circumferential
side of the magnet 1. The coil 2 includes an
electrical conductive wire wound on a bobbin 2a
formed of electrically-insulating material. The
thickness of the bobbin 2a in a direction of the
rotational axis is set slightly larger than that of
the magnet 1. One coil is sufficient since the

driving apparatus of this light-amount regulating apparatus adopts a method of one-phase driving.

Reference numeral 3 designates a first stator formed of soft magnetic material. The first stator 3 includes eight first magnetic pole portions 3a, 3b, 3c, 3d, 3e, 3f, 3g and 3h formed in a 45-degree equiangular form with a space between them. In other words, where the number of the magnetized poles in the magnet 1 is NA, an NA/2 number of the first magnetic pole portions are formed with an angular space of 720/NA degrees between them.

Reference numeral 4 designates a second stator formed of soft magnetic material. The second stator 4 includes eight second magnetic pole portions 4a, 4b, 4c, 4d, 4e, 4f, 4g and 4h formed in a 45-degree equiangular form with a space between them. In other words, where the number of the magnetized poles in the magnet 1 is NA, an NA/2 number of the second magnetic pole portions are also formed with an angular space of 720/NA degrees between them.

A cylindrical coupling portion 3i is formed on an outer circumferential portion of the first stator 3. The coupling portion 3i serves to couple the first stator 3 and the second stator 4 to each other. A portion of the first stator 3 other than its coupling portion 3i and the second stator 4 are formed by planer plates, respectively. Gear-shaped

radially-extending magnetic pole portions 3a to 3h
and 4a to 4h are formed by providing cutaway portions
in those planer plates, respectively. The coil 2 and
the magnet 1 are disposed within a space formed by

5   the coupled first and second stators 3 and 4. The
first stator 3 and one surface of the magnet 1, and
the second stator 4 and the other surface of the
magnet 1 are opposed to each other with predetermined
spaces therebetween, respectively.

10   When current is supplied to the coil 2, all the
first magnetic pole portions 3a to 3h are magnetized
into the same magnetic pole while all the second
magnetic pole portions 4a to 4h are magnetized into a
magnetic pole opposite to that of the first magnetic

15   pole portions 3a to 3h. The first stator 3 and the
second stator 4 are coupled with a common phase such
that the first magnetic pole portions 3a to 3h can
face the second magnetic pole portions 4a to 4h,
respectively. The first and second stators 3 and 4

20   coupled by the coupling portion 3i, and the coil 2
constitute a magnetic circuit. It is possible that
one of the first stator 3 and the second stator 4 is
formed by a planer plate without cutaway portions
while only the other stator is provided with magnetic

25   pole portions. Rotational torque is, however,
larger in the structure with magnetic pole portions
in both the first and second stators 3 and 4 than in

the structure discussed right above.

Reference numeral 11 represents a bearing ring fixed to an inner circumferential portion of the magnet 1. Reference numeral 12 represents a bearing

5   fixed between the first stator 3 and the second stator 4. The bearing ring 11 engages with an outer circumferential surface of the bearing 12, and slides on this surface while the magnet 1 continues to be positioned such that predetermined spaces can be

10 created between the magnet 1 and the first stator 3, and between the magnet 1 and the second stator 4, respectively.

Reference numeral 5 represents a plate 5 of the light-amount regulating apparatus. An aperture

15 portion 5a for forming the optical path is formed at a central portion of the plate 5. The first stator 3 is fixed to a surface of the plate 5, and a front plate 6 with an aperture portion 6a is fixed to the other surface of the plate 5. A space is provided

20 between the plate 5 and the front plate 6, and blade members 7, 8, 9 and 10 are disposed in this space.

Two driving pins 1h and 1i are formed on a surface of the magnet 1 facing the first stator 3. Those driving pins 1h and 1i are molded integrally

25 with the magnet 1 of plastic magnet material. Those driving pins 1h and 1i, therefore, can be formed with reduced positional error at relatively low cost,

compared with a case where driving pins are separately formed, and thereafter mounted to the magnet. Those driving pins 1h and 1i are inserted into arcuate elongate holes 5d and 5e formed in the plate 5, and can be moved in these elongate holes 5d and 5e along a circumferential direction.

Round holes 7a and 9a of the blade members 7 and 9 rotatably engage with the pins 5b and 5c of the plate 5, respectively, and elongate holes 7b and 9b slidably engage with the driving pin 1h of the magnet 1. Further, round holes 8a and 10a of the blade members 8 and 10 rotatably engage with the pins 5f and 5g of the plate 5, respectively, and elongate holes 8b and 10b slidably engage with the driving pin 1i of the magnet 1. When the magnet 1 is rotated, the blade members 7 and 9 are pushed by the driving pin 1h, and rotated about the round holes 7a and 9a in engagement with the pins 5b and 5c, respectively. The blade members 8 and 10 are also pushed by the driving pin 1i, and rotated about the round holes 8a and 10a in engagement with the pins 5f and 5g, respectively. Accordingly, the size of an aperture portion formed by the blade members 7, 8, 9 and 10 is varied, and hence the amount of light passing through the aperture portion 5a of the plate 5 can be regulated.

According to the above-discussed construction,

the thickness in the optical-axis direction of the
motor for driving the blade members 7, 8, 9 and 10
only amounts to the sum of the thickness of the
bobbin 2a slightly larger than that of the magnet 1,

5   and thicknesses of the first stator 3 and the second
stator 4. A drastically thin driving apparatus can
be hence constructed. Further, most of magnetic flux
flowing from one of the first magnetic pole portion
and the second magnetic pole portion flows into the

10   other magnetic pole portion disposed opposingly to
the one magnetic pole portion. The magnetic flux,
therefore, effectively acts on the magnet 1
interposed between those magnetic pole portions, and
large rotational torque can be obtained.

15   The rotational position of the magnet 1 will be
discussded.

          Figs. 3 and 4 are C-C cross-sectional views of
Fig. 2, respectively. Fig. 3 illustrates the
rotational conduction of the magnet 1 under which the

20   blade members 7 to 10 are closed (minimum aperture
diameter). Fig. 4 illustrates the rotational
conduction of the magnet 1 under which the blade
members 7 to 10 are retracted from the aperture
portion 5a of the plate 5 (maximum aperture diameter).

25   In the state of Fig. 3, when current in a
predetermined direction is supplied to the coil 2
such that the first magnetic pole portion in the

first stator and the second magnetic pole portion in
the second stator can be magnetized into the S pole
and the N pole, respectively, the central position of
the N pole on the back side of the magnet 1 (in Figs.

5   3 and 4, the back side of the magnet 1 faces the
first magnetic pole portion) tends to face the
central position of the first magnetic pole portion.
Hence, the magnet 1 is rotated in the clockwise
direction, and stopped at a position illustrated in

10   Fig. 4 in which the driving pin abuts the side wall
of the elongate hole 5d. Here, even if current flow
to the coil 2 is stopped, the magnet 1 is held at
this rotational position.

In the state of Fig. 4, when current in a

15   direction opposite to the above predetermined
direction is supplied to the coil 2 such that the
first magnetic pole portion and the second magnetic
pole portion can be magnetized into the N pole and
the S pole, respectively, the central position of the

20   S pole on the back side of the magnet 1 tends to face
the central position of the first magnetic pole
portion. Hence, the magnet 1 is rotated in the
counterclockwise direction, and stopped at a position
illustrated in Fig. 3 in which the driving pin abuts

25   the other side wall of the elongate hole 5d. Here,
even if current flow to the coil 2 is stopped, the
magnet 1 is held at this rotational position.

Fig. 5 is a graph showing the cogging torque acting between the coil 2 and the first and second stators 3 and 4. Its ordinate represents the magnitude of magnetic force (attractive force) generated between the magnet 1 and the first and second stators 3 and 4, and its abscissa represents the rotational phase of the magnet 1.

When the magnet 1 is in its rotational position indicated by the point E1 (E2), cogging torque capable of rotating the magnet 1 in the counterclockwise direction acts on the magnet 1 if the magnet 1 is going to be rotated in the clockwise direction by external force. Cogging torque capable of rotating the magnet 1 in the clockwise direction acts on the magnet 1 if the magnet 1 is going to be rotated in the counterclockwise direction by external force. Accordingly, the magnet 1 is returned toward the point E1 (E2). As a result, when the magnet 1 is in the position indicated by the point E1 or E2, the magnet 1 can be stably held at its position by the cogging torque even if no current is supplied to the coil 2.

The rotational position indicated by the point F1, F2 or F3 is similar to the point E1 or E2 in that the direction of action of cogging torque is switched to its opposite direction at such boundary point, but the action direction of the cogging torque is

opposite to that of the point E1 or E2. Therefore, the magnet 1 does not rotate so long as the rotational position of the magnet 1 is coincident with the point F1, F2 or F3. However, if the

5 rotational position deviates from the point F1, F2 or F3 due to slight changes in vibration and posture of the apparatus, cogging torque acts on the magnet 1 to rotate it up to one of the points E1 and E2 closest to the point F1, F2 or F3. Accordingly, considering

10 environment, such as vibration, in which the apparatus is actually used, it is impossible to stably hold the magnet 1 at the point F1, F2 or F3 by the cogging torque.

Rotational positions, such as those indicated

15 by the points E1 and E2, at which the magnet 1 is stably held by the cogging torque exist with intervals of 360/NA, where the number of magnetized poles in the magnet is NA. Intermediate positions between those stable positions are unstable positions

20 such as the points F1, F2 and F3.

From results of the numerical simulation by a finite element method, it becomes apparent that the attractive condition between the first magnetic pole portion and the magnet 1 at the time when no current

25 flow is supplied to the coil varies according to the relationship between the size of the magnet 1, the angle of each magnetized pole in the magnet 1 (a

portion B illustrated in Fig. 3 which is the central angle of the magnetized portion in the magnet 1), and the opposing angle of the first magnetic pole portion opposed to the magnet 1 (a portion A illustrated in Fig. 3 which is an arcuate central angle formed by the first magnetic pole portion and the rotational center position of the rotor).

According to the above result, positions of the stable points E1 and E2 vary according to the size of the magnet, the central angle of the magnetized portion in the magnet, and the central angle of the first magnetic pole portion. In other words, according to their changes, there separately occur cases where the center of the magnetized portion in the magnet 1 is stably held at a position in which this center faces the center of the first magnetic portion, and cases where the boundary between the magnetized portions in the magnet 1 is stably held at a position in which this boundary faces the center of the first magnetic portion. This situation will be described with reference to Fig. 6.

In Fig. 6, its abscissa represents a ratio of the thickness of the magnet (the thickness in a direction of its rotational axis) relative to the outer circumferential length of each magnetic pole in the magnet, and its ordinate represents a ratio of the opposing angle of each magnetic pole portion

facing the magnet relative to the angle of each

magnetic pole in the magnet (i.e., a ratio of the

central angle of each magnetic pole portion relative

to the central angle of each pole in the magnet).

5   For example, when the outer diameter of the

magnet is 18 mm, its thickness is 0.05 mm, and the

number of magnetic poles in the magnet is sixteen

(16), the outer circumferential length of each

magnetic pole in the magnet is $18 \times \pi /16$, and hence

10   the value on the abscissa of the ratio of the

thickness of the magnet relative to the outer

circumferential length of each pole in the magnet

becomes 0.141. Further, when the central angle of

each magnetic pole portion is 13.5 degrees, the value

15   on the ordinate of the ratio of the opposing angle of

each magnetic pole portion facing the magnet relative

to the angle of each pole in the magnet becomes 0.600

since the central angle of each pole in the magnet is

22.5 degrees.

20   In Fig. 6, each plotted point indicates the

ratio of the opposing angle of each magnetic pole

portion facing the magnet relative to the angle of

each magnetic pole in the magnet in a model having

the smallest cogging torque. Fig. 6 shows the graph

25   of fourteen (14) types of motors described in the

table of Fig. 7.

       In Fig. 6, where its abscissa X represents the

ratio of the thickness of the magnet relative to the outer circumferential length of each magnetic pole in the magnet, and its ordinate Y represents the ratio of the opposing angle of each magnetic pole portion

5   facing the magnet relative to the angle of each magnetic pole in the magnet, above points fall within a region surrounded with the line 1 approximately defined by $Y=-0.333X+0.7$ and the line 2 approximately defined by $Y=-0.333X+0.9$.

10   In Fig. 6, in a region below the line 1 (i.e., a region of $Y<-0.333X+0.7$) the center of the pole in the magnet is stably held at a position in which this center faces the center of the magnetic pole portion, and in a region above the line 2 (i.e., a region of

15   $Y>-0.333X+0.9$) the boundary between the poles in the magnet is stably held at a position in which this boundary faces the center of the magnetic pole portion.

        In the region surrounded by the line 1 and the

20   line 2 (i.e., where the condition of $-0.333X+0.7<Y<-0.333X+0.9$ is satisfied), the cogging torque becomes smallest, and hence the points E1 and E2 whereat the magnet is stably held do not apparently appear.

        Experimental results are shown in Figs. 8, 9

25   and 10.

        In Figs. 8, 9 and 10, similar to Fig. 5, the ordinate represents the magnitude of magnetic force

(attractive force) generated between the magnet 1 and the first and second stators 3 and 4, and the abscissa represents the rotational phase of the magnet 1. There are shown cogging torque at the time when no current is supplied to the coil 2, and current-supply torque generated when a voltage of 3 V is applied across terminals of the coil 2. In this motor model, the outer diameter of the magnet is 16 mm, the inner diameter of the magnet is 14 mm, the number of magnetized poles in the magnet is 40, the turn number of the coil is 105 turns, the resistance is 1065 Ω, and the outer diameter of the stator is 19.1 mm.

In Fig. 8, the central angle of the magnetic pole portion (indicated by A in Fig. 3) is 4.5 degrees, X=0.455, and Y=0.50. In Fig. 9, the central angle of the magnetic pole portion is 5.63 degrees, X=0.455, and Y=0.625. In Fig. 10, the central angle of the magnetic pole portion is 7.2 degrees, X=0.455, and Y=0.80.

In Fig. 11 illustrating lines 1 and 2, structures of Figs. 8, 9 and 10 are indicated by A, B and C, respectively.

In the apparatus having structural characteristics shown in Fig. 8 (i.e., the apparatus in which the central angle A of the magnetic pole portion is 4.5 degrees), X=0.455 and Y=0.50.

Therefore, the condition of Y<-0.333X+0.7 is satisfied, and the stable position of the magnet is a position in which the pole center of the magnetized portion faces the center of the magnetic pole portion.

5   In the apparatus having structural characteristics shown in Fig. 9 (i.e., the apparatus in which the central angle A of the magnetic pole portion is 5.63 degrees), X=0.455 and Y=0.50. Therefore, the condition of -0.333X+0.7<Y<-0.333X+0.9

10   is satisfied, and the cogging torque is very small.

In the apparatus having structural characteristics shown in Fig. 10 (i.e., the apparatus in which the central angle A of the magnetic pole portion is 7.2 degrees), X=0.455 and Y=0.80.

15   Therefore, the condition of Y>-0.333X+0.9 is satisfied, and the stable position of the magnet is a position in which the boundary between poles of the magnetized portions faces the center of the magnetic pole portion.

20   In the above-discussed first embodiment, the size of the driving apparatus is set so as to satisfy Y>-0.333X+0.7. Accordingly, when no current is supplied to the coil 2, the points E1 and E2 are positions in which the center of the magnetized

25   portion in the magnet 1 faces the central positions of the first and second magnetic pole portions. The magnet 1 is hence stably held at this position even

if no current is supplied to the coil 2.

If, however, the center of the magnetized portion in the magnet 1 fully faces the central positions of the first and second magnetic pole portions, the magnet 1 cannot be rotated even when the direction of current supplied to the coil 2 is switched because equivalent torques in the clockwise direction and the counterclockwise direction act on the magnet 1. Therefore, the rotatable range of the magnet 1 is restricted by the elongate hole 5d (5e) in engagement with the driving pin 1h (1i) in such a manner that the center of the magnetized portion in the magnet 1 cannot fully face the central positions of the first and second magnetic pole portions.

When the magnet 1 is rotated in the counterclockwise direction, the driving pin 1h abuts the side wall of the elongate hole 5d at a position α degrees before the position in which the center of the magnetized portion in the magnet 1 faces the center R1 of the magnetic pole portion 3a in the first stator. The rotation of the magnet 1 is thus stopped. At this moment, the rotational position of the magnet 1 is the point G illustrated in Fig. 5, and holding torque of the magnet 1 due to cogging torque (torque for rotating the magnet 1 in the counterclockwise direction, i.e., torque for rotating the magnet 1 to the point E1 illustrated in Fig. 5)

is T1. In this state, when the first magnetic pole
portion 3a and the second magnetic pole portion
facing this first magnetic pole portion are
magnetized into the S pole and the N pole,

5   respectively, the magnet 1 is rotated in the
clockwise direction.

When the magnet 1 is rotated in the clockwise
direction, the driving pin 1h abuts the side wall of
the elongate hole 5d at a position β degrees before

10   the position in which the center of the magnetized
portion in the magnet 1 faces the center R2 of the
magnetic pole portion 3b in the first stator. The
rotation of the magnet 1 is thus stopped. At this
moment, the rotational position of the magnet 1 is

15   the point H illustrated in Fig. 5, and holding torque
of the magnet 1 due to cogging torque (torque for
rotating the magnet 1 in the clockwise direction,
i.e., torque for rotating the magnet 1 to the point
E2 illustrated in Fig. 5) is T2. In this state, when

20   the first magnetic pole portion 3a and the second
magnetic pole portion facing this first magnetic pole
portion are magnetized into the N pole and the S pole,
respectively, the magnet 1 is rotated in the
clockwise direction.

25   When α and β are set such that the stable
positions E1 and E2 illustrated in Fig. 5 cannot fall
within ranges of α and β, the magnet 1 is always

held at the position illustrated in Fig. 3 or Fig. 4
due to the cogging torque if no current is supplied
to the coil 2. If the holding position of the magnet
1 is to be switched, current only needs to be

5   supplied to the coil 2 such that the magnet 1 can be
rotated to a position beyond the F2 at which the
direction of cogging torque is switched.

If α and β are set such that the stable
positions E1 and E2 fall within ranges of α and β,

10 the center of the magnetized portion in the magnet 1
cannot fully faces the central positions of the first
and second magnetic pole portions as discussed above.
Accordingly, the magnet 1 cannot be rotated since
equivalent torques in the clockwise direction and the

15 counterclockwise direction act on the magnet 1 even
if the direction of current supplied to the coil 2 is
switched.

As described in the foregoing, the blade
members 7 to 10 are rotated in interlocking

20 relationship with the magnet 1. When the magnet 1 is
in the state of Fig. 3, the blade members 7 to 10 are
brought into positions in which they are not
superposed on the aperture portion 5a of the plate 5.
When the magnet 1 is in the state of Fig. 4, the

25 blade members 7 to 10 are brought into positions in
which they are closed, and superposed on the aperture
portion 5a of the plate 5. The aperture portion 5a

is hence closed. Therefore, the blade members 7 to 10 can be selectively brought into the open state or the closed state by switching the current supply to the coil 2. The amount of light passing through the

5   aperture portion 5a can be hence controlled.

Further, even if current supply to the coil 2 is stopped in those open and closed states, the position of the magnet 1 is maintained due to the cogging torque. Accordingly, even if external

10   disturbance such as vibration occurs, positions of the blade members 7 to 10 can be maintained without consuming electric power. Thus, reliability of the shutter or the stop can be improved, and power consumption can be reduced.

15   Furthermore, the lens can be arranged within the light-amount regulating apparatus by making this apparatus in a ring shape.

Fig. 12 is a disassembled perspective view illustrating a second embodiment of a light-amount

20   regulating apparatus according to the present invention. In Fig. 12, portions having equivalent functions to those of the first embodiment are designated by the same reference numerals as those of the first embodiment, and detailed description

25   thereof will be omitted.

While the first embodiment relates to the light-amount regulating apparatus in which the

positions of the blade members 7 to 10 can be controlled between open positions (maximum aperture diameter) and closed positions (minimum aperture diameter), the second embodiment relates to a light-

5 amount regulating apparatus in which the amount of light entering an image pick-up device is regulated according to luminance of the object field. In the light-amount regulating apparatus of the second embodiment, an ND (neutral density) filter plate is

10 driven in interlocking relationship with rotation of the magnet 1, and the amount of light passing through the aperture portion 5a is regulated by changing the condition of light entering the aperture portion.

Reference numeral 13 designates the ND filter

15 plate which is a light-amount regulating member. A round hole 13a of the filter plate 13 rotatably engages with the pin 5b of the plate 5, and an elongate hole 13b slidably engages with the driving pin 1h of the magnet 1. Similar to the blade members

20 7 to 10 of the first embodiment, when the magnet 1 is rotated, the ND filter plate 13 is pushed by the driving pin 1h, and rotated about the round hole 13a engaging with the pin 5b. Accordingly, the condition can be changed between a condition under which the ND

25 filter 13c is brought into the front of the aperture portion 5a of the plate 5, and a condition under which the ND filter 13c is retracted from the

aperture portion 5a of the plate 5. The amount of
light passing through the aperture portion 5a can be
hence regulated.

Even if current supply to the coil 2 is stopped,
the above conditions of the ND filter 13c
superimposed on and retracted from the aperture
portion 5a can be maintained. Accordingly, power
consumption can be reduced.

Fig. 13 is a disassembled perspective view
illustrating a third embodiment of a light-amount
regulating apparatus according to the present
invention. In Fig. 13, portions having equivalent
functions to those of the first embodiment are
designated by the same reference numerals as those of
the first embodiment, and detailed description
thereof will be omitted.

In the third embodiment, a movable stop
aperture plate with an aperture portion smaller than
the the aperture portion 5a is used in place of the
ND filter plate 13 in the second embodiment.

In Fig. 13, reference numeral 20 designates the
stop aperture plate which is formed of plastics or
metal having light intercepting characteristic. A
round hole 20a of the stop aperture plate 20
rotatably engages with the pin 5b of the plate 5, and
an elongate hole 20b slidably engages with the
driving pin 1h of the magnet 1. When the magnet 1 is

rotated, the stop aperture plate 20 is pushed by the driving pin 1h, and rotated about the round hole 20a engaging with the pin 5b. Accordingly, the condition can be changed between a condition under which a stop

5   aperture portion 20c having a diameter smaller than that of the aperture portion 5a is brought into the front of the aperture portion 5a of the plate 5, and a condition under which the stop aperture portion 20c is retracted from the aperture portion 5a of the

10   plate 5. The amount of light passing through the aperture portion 5a can be hence regulated.

Also in this embodiment, even if current supply to the coil 2 is stopped, the above conditions of the stop aperture portion 20c superimposed on and

15   retracted from the aperture portion 5a can be maintained. Accordingly, power consumption can be reduced.

Fig. 14 is a cross-sectional view illustrating a fourth embodiment of a lens driving apparatus

20   according to the present invention. In Fig. 14, portions having equivalent functions to those of the first embodiment are designated by the same reference numerals as those of the first embodiment, and detailed description thereof will be omitted.

25   The fourth embodiment relates to an apparatus in which the position of a lens can be readily switched between two stop positions by using the

driving apparatus used in the above embodiments. Those two lens stop positions are, for example, a lens position suitable for photographing an infinite far object, and a lens position suitable for

5   photographing a short distance object.

Reference numeral 31 designates a cylindrical lens-barrel member. A female helicoidal portion is formed on its inner circumferential portion, and the first stator 3 is fixed to the lens-barrel member 31.

10   Reference numeral 32 designates a lens holding member for holding the lens disposed in the inner circumferential portion of the lens-barrel member 31. A male helicoidal portion is formed on its outer circumferential portion, and the male helicoidal

15   portion rotatably engages with the female helicoidal portion of the lens-barrel member 31. Round holes 32a and 32b are formed in the lens holding member 32, and the driving pins 1h and 1i of the magnet 1 engage with the round holes 32a and 32b, respectively.

20   When the magnet 2 is rotated, the lens holding member 32 is guided by the driving pins 1h and 1i, and rotated. Accordingly, the lens holding member 32 and the lens 33 are moved in a direction of its optical axis due to interaction between the male

25   helicoidal portion and the female helicoidal portion. The focal length of a light beam passing through the central portion of the magnet 1 can be hence changed.

Lengths of the driving pins 1h and 1i need to have sufficient values that can maintain the engagement condition even when the lens holding member 32 moves in the direction of its optical axis.

5   Also in this embodiment, even if current supply to the coil 2 is stopped, the lens position can be maintained. Accordingly, its structure can be simplified, and power consumption can be reduced. Further, since inner portions of the magnet 1 and the 10 stators 3 and 4 are used as the optical path, the lens driving apparatus can be made smaller than a case where the motor is disposed radially adjacent to the lens.

In the above-discussed embodiments, the number 15 of magnetic poles of the magnet is sixteen, but modified structures can have at least two magnetic poles including one N pole and one S pole. Similarly, the first magnetic pole portions and the second magnetic pole portions are comprised of gear 20 configurations with plural teeth, respectively, but modified structures can have at least one gear-shaped magnetic pole portion facing two poles of the N pole and the S pole in the magnet.

As described in the foregoing, according to the 25 above embodiments, even if current supply to the coil provided in the driving apparatus is stopped, the rotor comprised of the magnet can be maintained in

two predetermined positions. Further, power

consumption in the apparatus can be reduced.